Sample MS-Word

INTERMOUNTAIN POWER SERVICE CORPORATION
Intermountain Generating Station (IGS) UNIT 1 and 2

HP TURBINE UPGRADE PROJECT

Test Procedure for:
Verifying guaranteed HP TURBINE EFFICIENCY TEST
and benchmarking TURBINE CYCLE HEAT RATE

Aaron Nissen
12/04/01

Revision #/ Date: ______________

IP7010878

Table of Contents

IP7010879

UNIT 1

HP TURBINE UPGRADE PROJECT

PROCEDURE FOR
HP TURBINE EFFICIENCY TEST

INTRODUCTION

This procedure defines the HP turbine efficiency test that will be undertaken to demonstrate that the guarantee performance requirements of the Contract have been met. The tests will be carried out by a third party test agency under the direction of the Intermountain Power Service Corporation (IPSC) and witnessed by ALSTOM POWER.

The third party test agency will supply and install test instrumentation to the requirements of ASME PTC 6.

The test will be carried out in accordance with the contract and ASME PTC 6: 1996 "Performance Test Code on Steam Turbines", except as otherwise mutually agreed between IPSC and ALSTOM.

1 OBJECTIVE OF TESTS

The objective of the test is to measure the HP turbine efficiency and steam swallowing capacity, following installation of the upgraded HP turbine.

2 CONTRACTUAL GUARANTEE

2.1 The HP turbine section upgrades provided by ALSTOM are guaranteed to provide the following HP turbine efficiencies (main steam valve inlet to HP turbine exhaust) when operating the turbine with all nozzle control valves wide open, at the new rated steam conditions:

X % guaranteed HP turbine efficiency for the upgrade designed for a 3+1 valve sequence. This value includes the effect of the indicated HP valve pressure drop at two point nine percent (2.9%).

For information purposes, the expected HP section efficiency at the same conditions but excluding valves is Y %.

2.2 ALSTOM guarantees that the swallowing capacity of the HP turbine at the specified conditions will be Z lb/hr.

3 SCOPE OF TESTS

3.1 Guarantee Tests

The HP cylinder efficiency achieved from the blading upgrade will be verified by an enthalpy drop test. This test will be conducted as soon as practicable after steam is readmitted to the unit; this should not be more than 8 weeks after the unit is re-synchronized. During the tests the unit will operate as close as possible to the normal maximum operation conditions with all the nozzle control valves wide open.

The results of the tests will be corrected (as appropriate) for any significant variations of the relevant terminal conditions from those specified, using correction factors agreed in advance of the tests, before comparison with guarantees.

The HP turbine steam swallowing capacity will be calculated from the main steam flow at inlet to the turbine stop valves, derived from measurements using the condensate flow section. Heat balances will be calculated around the HP heaters and the deaerator to determine the flow to the boiler and hence steam flow to the turbine stop valve.

3.2 Benchmark Tests

Benchmark enthalpy drop tests will be taken periodically from the time of initial loading of the turbine and the results recorded for reference purposes.

4 TEST PREPARATION

4.1 Plant Operation and Control

Before starting the performance tests on the turbine generator unit, all relevant plant automatic control systems are to be set and working effectively to achieve the required values and stability of the operating steam conditions.

All feed water heaters will be in service and operating normally.

4.2 Work Carried Out during Replant Outage

During the outage NSP will check all relevant instrument tappings and make sure that they are suitable for use during the tests.

Pressure tapping points, which have been capped off, will need to be re-instated and piped down to convenient location. Any new pressure tappings, such as pressure at HP turbine inlet, will need to be installed during the outage.

The bore of thermowells will be checked for blockage and cleaned if necessary.

5 TEST INSTRUMENTATION

Appendix I contains the test instrument list. NSP will supply and install test instruments, of the accuracy called for in the test code.

5.2 Pressure Measurement

Calibrated 0.1% accuracy pressure transducers will measure all static pressures. All measured pressures will be corrected for the static water leg and, where appropriate, atmospheric pressure.

Atmospheric pressure will be measured using a precision barometer.

5.3 Temperature Measurements

All temperatures will be measured using calibrated platinum resistance thermometers located in thermometer wells.

5.4 Flow Measurement

The initial assessment of the steam swallowing capacity of the steam turbine will be made by measuring the condensate flowrate using the currently installed condensate flow nozzle section. This flow section will not be calibrated or changed prior to any of the testing. If the initial assessment of the steam swallowing capacity suggests that the guaranteed value has not been achieved within the specified tolerance, then the currently installed condensate flow nozzle section will be replaced with a calibrated flow nozzle section, and the steam swallowing capacity of the steam turbine will be re-measured.

NSP will bear all costs associated with supplying and fitting of the new calibrated flow section, unless the re-test confirms that the steam swallowing capacity is outside the specified tolerances. In this event ALSTOM will bear all costs associated with supplying and fitting the new calibrated section.

The flow will also be calculated using the recently installed feedwater flowmeter as a crosscheck against the flowrate derived from the condensate flow section. This flow will also be taken into account before deciding to install the new calibrated flow section.

The differential pressure across the condensate and feedwater flow nozzles will be measured by duplicate 0.1% calibrated differential pressure transducers. All other subsidiary flowmeters will be measured by single 0.1% calibrated differential pressure transducers.

5.5 Data Acquisition System

All output signals from pressure transducers and resistance thermometers will be recorded automatically using a computer controlled data acquisition system.

6 CALIBRATION OF TEST INSTRUMENTATION

NSP will calibrate all instruments before the tests, using transfer standards traceable to National Standards. Re-calibration following the test, will only take place where Alstom and NSP agree the requirement is necessary.

7 TEST PROCEDURE

7.1 Plant Operation and Safety

NSP will appoint a 'Test Controller' to co-ordinate the running of the plant, to arrange satisfactory conditions for of each test, and to liaise with all the test engineers.

The operations staff will take any action needed to maintain safety during the course of a test. The Test Controller will immediately advise the test engineers of any changes to the operating conditions or plant isolation. NSP and ALSTOM will then agree whether to continue or abandon the test.

7.2 Valve Isolation List

NSP will produce a valve isolation list so the all valves requiring closure during the test can be tagged , and checked for correct closure during the test.

7.3 Number and Duration of Tests

Two VWO (valves wide-open) performance tests, each of a nominal 1 hour duration will be carried out. The tests will be compared for repeatability and repeat tests carried out if the results are inconsistent.

7.4 Frequency of Readings

Pressure and temperature readings will be automatically logged at intervals no greater than 1 minute.

7.5 Terminal Conditions

The HP turbine efficiency will not vary significantly over a wide range of inlet pressures and temperatures. However, for test accuracy reasons, it is essential that the performance tests be conducted with all of the control valves in the fully open position. Terminal conditions must also be held steady as near to the proposed test values as possible for at least 1 hour before the start of the test. Further, the maximum permissible fluctuation of the inlet conditions from the mean during any one test run, as allowed by ASME PTC 6: 1996 are: -

Variable	Maximum Permissible Fluctuation From Test Average
Steam pressure before HP stop valve	±0.25% of absolute pressure
Steam temperature before HP stop valve	±7 °F

Note: By mutual agreement between all parties involved, it is acceptable to conduct tests with deviations outside the limit set out in the table.

8 CALCULATION OF RESULTS

8.1 HP Turbine Efficiency

The detailed calculation methods for the various tests are shown on the calculation sheets in Appendix II of this procedure.

The HP cylinder efficiency is defined as follows:

$$HPefficiency = \frac{h_1 - h_2}{h_1 - h_2'}$$

Where, h_1 = steam enthalpy before HP turbine stop valves

h_2 = steam enthalpy at HP exhaust

h_2' = steam enthalpy at HP exhaust assuming isentropic expansion from before the main steam valves

8.2 Steam Swallowing Capacity

The mass throttle flowrate will be derived from the measured condensate flowrate by taking into consideration the steam flowrate to the HP heaters and deaerator, and also any secondary flows such as spraywater, auxiliary steam and known boiler losses.

The calculated steam swallowing capacity will be corrected to the design steam inlet conditions of 2460 psig and 1000 ° F. The average of the two VWO tests will used to calculate the test results for comparison with the guarantee based on the equation below:

$$m_{1corr} = m_{1test} \times \frac{\sqrt{(p_{design} \times \upsilon_{test})}}{\sqrt{(p_{test} \times \upsilon_{design})}}$$

Where m_{1corr} = mass flowrate at turbine stop valve corrected to design steam inlet conditions (lb/h)

m_{1test} = test mass flowrate at turbine stop valve (lb/h)

p_{test} = test steam pressure at TSV (psia)

p_{design} = design steam pressure at TSV (psia)

υ_{test} = test steam specific volume at TSV (ft^3/lb)

υ_{design} =design steam specific volume at TSV (ft^3/lb)

8.3 Test Tolerances and Allowances

8.3.1 Measurement Uncertainty

HP Turbine Efficiency

HP turbine efficiency is derived from measurements of associated pressures and temperatures which are subject to measurement uncertainty.

Tolerances for measurement uncertainty applied to the efficiency test results shall be calculated using the actual test instrument uncertainties and shall not exceed 0.5%

HP Turbine Swallowing Capacity

The steam swallowing capacity shall be between the limits of:

8.3.2 Excessive Deterioration

ASME PTC 6 Report-1985 gives guidance in clauses 3.06 and 3.07 on the average expected performance deterioration cause by delayed tests. An additional allowance will apply to the guarantee test result if the benchmark tests show that the deterioration between initial steaming and the guarantee test is excessive. This allowance will equal the difference between the measured deterioration and the ASME guidance norm and will be added arithmetically to the tolerance for measurement uncertainty. For this turbine configuration , the HP turbine is taken to account for approximately 50% of the total degredation.

8.3.3 Delayed Testing

If the tests are delayed beyond the recommended 8 weeks after re-synchronisation, a deterioration allowance equal to the ASME guidance norm will be applied to the results. This allowance will be added arithmetically to the tolerance for measurement uncertainty. For this turbine configuration, the HP turbine is taken to account for approximately 50% of the total degredation.

8.3.4 Steam Tables

The 1967 steam tables will be used in the calculation of the test results.

APPENDIX 1

Schedule of Readings and Instrumentation

The following abbreviations are used to describe the type of instrument required in this schedule :-

PT	Pressure transducer
B	Barometer
PRT	Platinum resistance thermometer
DPT	Differential Pressure Transducer

INTERMOUNTAIN GENERATING STATION UNIT 2

Schedule of Readings and Instrumentation

TEST REF.	PRESSURE MEASUREMENT	TAPPING REF	EXPECTED READING psig	INST TYPE	INST RANGE psig	TEMP or STATION	ACCURACY %
P1	Steam before HP stop valve A	Test Connection	2460	PT	3000	TEMP	0.1
P2	Steam before HP stop valve B	Test Connection	2460	PT	3000	TEMP	0.1
P3	Steam before HP stop valve B	Test Connection	2460	PT	3000	TEMP	0.1
P4	Steam after HP stop valves (steam chest)	PT 1005	2400	PT	3000	TEMP	0.1
P5	Steam at HP inlet (CV#1)	Test Connection	2389	PT	3000	TEMP	0.1
P6	Steam at HP inlet (CV#2)	Test Connection	2389	PT	3000	TEMP	0.1
P7	Steam at HP inlet (CV#3)	Test Connection	2389	PT	3000	TEMP	0.1
P8	Steam at HP inlet (CV#4)	Test Connection	2389	PT	3000	TEMP	0.1
P9	Steam at 1st Stage	PT1020	2000	PT	3000	TEMP	0.1
P10	Steam at HP exhaust A	Test Connection	634	PT	1000	TEMP	0.1
P11	Steam at HP exhaust B	Test Connection	634	PT	1000	TEMP	0.1
P12	Condensate at Deaerator inlet		100	PT	150	STATION	0.2
P13	Condensate at deaerator outlet		100	PT	150	STATION	0.2

Schedule of Readings and Instrumentation

TEST REF.	PRESSURE MEASUREMENT	TAPPING REF	EXPECTED READING psig	INST TYPE	INST RANGE psig	TEMP or STATION	ACCURACY %
P14	Feedwater at HP 6 inlet		3000	PT	3500	STATION	0.2
P15	Feedwater at HP 7 inlet		3000	PT	3500	STATION	0.2
P16	Feedwater at HP 7 outlet (final feedwater)		3000	PT	3500	STATION	0.2
P17	Steam at Deaerator		65	PT	150	STATION	0.1
P18	Steam at HP 6		270	PT	300	STATION	0.1
P19	Steam at HP 7		615	PT	1000	STATION	0.1
P20	Atmospheric pressure			B		STATION	

INTERMOUNTAIN GENERATING STATION UNIT 2

Schedule of Readings and Instrumentation

TEST REF	DIFFENTIAL PRESSURE MEASUREMENT	TAPPING REF	EXPECTED READING INS WATER	INST TYPE	TEMP or STATION	ACCURACY %
F1	Condensate Flow Tap A			DPT	STATION	0.1
F2	Condensate Flow Tap B			DPT	STATION	0.1
F3	Feedwater Flow A			DPT	STATION	0.1
F4	Feedwater Flow B			DPT	STATION	0.1
F5	Spraywater			DPT	STATION	0.1
F6	Deaerator Level			DPT	STATION	0.1
F7	Condenser Level			DPT	STATION	0.1

INTERMOUNTAIN GENERATING STATION UNIT 2

Schedule of Readings and Instrumentation

TEST REF.	TEMPERATURE MEASUREMENT	TAPPING REF	EXPECTED READING °F	INST TYPE	INST RANGE °F	TEMP or STATION	ACCURACY °F
T1	Steam before HP stop valve A1	TW1020	1000	PRT	1100	TEMP	0.5
T2	Steam before HP stop valve A2	TW1022	1000	PRT	1100	TEMP	0.5
T3	Steam before HP stop valve B1	TW1034	1000	PRT	1100	TEMP	0.5
T4	Steam before HP stop valve B2	TW1035	1000	PRT	1100	TEMP	0.5
T5	Steam before HP stop valve C1	TW1021	1000	PRT	1100	TEMP	0.5
T6	Steam before HP stop valve C2	TW1023	1000	PRT	1100	TEMP	0.5
T7	Steam at HP exhaust A1	TW1024	633	PRT	1100	TEMP	0.5
T8	Steam at HP exhaust A2	TW1026	633	PRT	1100	TEMP	0.5
T9	Steam at HP exhaust B1	TW1025	633	PRT	1100	TEMP	0.5
T10	Steam at HP exhaust B2	TW1027	633	PRT	1100	TEMP	0.5
T11	Condensate at Deaerator inlet		312	PRT	600	STATION	0.2
T12	Condensate at Dearator outlet		364	PRT	600	STATION	0.2
T13	Feedwater at HP 6 inlet		371	PRT	600	STATION	0.2
T14	Feedwater at HP 7 inlet		415	PRT	600	STATION	0.2
T15	Feedwater at HP 7 outlet		491	PRT	600	STATION	0.2
T16	Feedwater at HP 7 outlet (after bypass)		491	PRT	600	STATION	0.2

INTERMOUNTAIN GENERATING STATION UNIT 2

Schedule of Readings and Instrumentation

TEST REF.	TEMPERATURE MEASUREMENT	TAPPING REF	EXPECTED READING °F	INST TYPE	INST RANGE °F	TEMP or STATION	ACCURACY °F
T17	HP 6 heater drain		381	PRT	600	STATION	0.2
T18	HP 7 heater drain		425	PRT	600	STATION	0.2

IP7010891

APPENDIX 2

Calculations

IP7010892

POWER PLANT UNIT 1

Test No. Date: .

Nominal Load MW Test Period: .

CALCULATION OF HP TURBINE EFFICIENCY

	Pressure	Temperature	Enthalpy	Entropy
	psia	°F	Btu/lb	Btu/lb °R
Steam before HP stop valve			h_1	
Steam at HP cylinder inlet				
Steam at HP exhaust			h_2	
Steam at isentropic point			h_2'	

$$\text{HP Turbine Efficiency} = \frac{(h_1 - h_2)}{(h_1 - h_2')} \times 100\%$$